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How does deprivation influence secondary care costs after hip fracture?

Joel Glynn[1], William Hollingworth[1], Arti Bhimjiyani[2], Yoav Ben-Shlomo[3] and Celia L Gregson[2]

Affiliations: 1. Health Economics at Bristol, Bristol Medical School, University of Bristol, Bristol, UK 2. Musculoskeletal Research Unit, Bristol Medical School, University of Bristol, Bristol UK. 3.Population Health Sciences, Bristol Medical School, University of Bristol, Bristol, UK

Corresponding Author:
Joel Glynn
Address: 1-5 Whiteladies Road
Bristol, UK
BS8 1NU
Tel. 0117 42 83115
email: joel.glynn@bristol.ac.uk

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Conflicts of Interest
The Authors declare they have no conflicts of interest.

Abstract:

Purpose: To quantify differences in hospital costs following hip fracture between those living in higher and lower deprivation areas of England. We investigate pre and post-fracture variables that explain the association.

Methods: We used English Hospital Episodes Statistics linked to the National Hip Fracture Database (04/2011-03/2015) and national mortality data to identify patients admitted with hip fracture aged 60+ years. Hospital care was costed using 2017/18 national reference costs, by Index of Multiple Deprivation quintile. Three generalised linear model regressions estimated associations between deprivation and costs, and the pre- and post-fracture variables that mediate this relationship.

Results: Patients from the most deprived areas had higher hospital costs in the year post-fracture (£1,120; 95% CI £993 to £1,247) than those from the least deprived areas. If all patients could have incurred similar costs to those in the least deprived quintile, this would equate to an annual reduction in expenditure of £28.8 million. Pre-fracture characteristics, particularly comorbidities and anaesthetic risk grade, accounted for approximately 50% of the association between deprivation and costs. No evidence was found that post-fracture variables, such as transfer to a residential or nursing home, contributied to the association between deprivation and costs.

Conclusions: Socioeconomic inequalities are associated with substantial costs for the NHS after hip fracture. We did not identify post-fracture targets for intervention to reduce the impact of inequalities on post fracture costs. The case for interventions to reduce comorbid conditions, improve health-related behaviours and prevent falls in deprived areas is clear but challenging to implement.

Keywords Hip fracture; Cost; Deprivation; Secondary Care; Inequalities; Economics; Osteoporosis

Mini abstract:

We studied the association between deprivation and healthcare costs after hip fracture. Hospital costs in the year following hip fracture were £1,120 higher for those living in more deprived areas. Most of this difference was explained by pre-existing health inequalities which should be targeted to reduce this disparity.

Introduction

Hip fractures are a common serious injury for ageing populations. In 2017, 60,060 people aged 60 years or older, were admitted to hospitals across England as a direct result of a hip fracture [1]. At any one time around 1 in 45 National Health Service (NHS) hospital beds in England are occupied by individuals recovering from a hip fracture [1]. Consequently, treatment for this injury represents a significant opportunity cost to the NHS, with estimated secondary care (*i.e.* hospital) costs increased by as much as £869 million per year in this older population [2]. Despite this investment, only a minority of patients regain their pre-fracture function. High post-fracture dependency results in one quarter needing long-term residential or nursing care [1].

Key predictors of higher healthcare costs following hip fracture include: comorbidity; discharge to a location other than home; and suffering a second fragility fracture [2, 3]. Work across a broad range of health conditions has found secondary care costs are 27-31% higher in older populations from the most deprived locations compared to those in the least deprived areas [4, 5]. However, to date there has been little evidence for the association between socioeconomic deprivation and the costs of treating hip fracture.

Our primary objective was to quantify any association between deprivation and secondary care costs in the year following a hip fracture. We hypothesised that a better understanding of this association and its mediators might help to identify interventions to reduce health costs, improve patient outcomes and reduce health inequalities. We further hypothesised that being from a more deprived location would make transfer to a care home more difficult because of financial and social support barriers, and therefore would result in longer lengths of hospital stay with subsequently higher NHS costs. We aimed to: 1) estimate the overall association between deprivation and secondary care costs; 2) estimate the proportion of any association between deprivation and post-fracture costs that can be explained by pre-fracture variables; such as pre-fracture health status; 3) explore whether post-fracture variables such as care transitions (which may be amenable to intervention) act as mediators in the association between deprivation and post-fracture costs.

Methods

Data Sources

Anonymised patient-level data were obtained from the routinely collected Hospital Episodes Statistics (HES) Admitted Patient Care (APC) database that included admissions to all English NHS hospitals for the period 1st April 2011 to 31st March 2015. This HES data extract was linked by NHS Digital, the national health and social care data provider, to Office for National Statistics (ONS) mortality data for the same 4-year period, which provided death status at specified time points (days 7, 30, 120, 365). The resulting HES-ONS data extract was then linked to an extract from the UK's National Hip Fracture Database (NHFD) [1]. A quality of linkage assessment was undertaken. Good linkage was defined as having a matching date of admission (within 10 days), age (within 1 year), sex, and hospital provider code [6].

HES includes information on patient demographics and up to 20 clinical diagnoses using International Classification of Diseases, Tenth Revision (ICD-10) codes [7]. ONS mortality data are obtained from death certificates of all registered deaths in England and Wales, thus capturing deaths that occurred outside hospital. The NHFD is a national clinical audit of hip fracture care provided by 175 NHS hospitals in England, Wales and Northern Ireland [1]. Each NHFD record includes information on patient demographics, hip fracture type, pre- and post-fracture mobility, use of bone protection medication, surgical delay and operations performed.

Study population

Patients were identified for analysis if they had an admission with a primary diagnosis code for hip fracture (fracture of the neck of the femur): Intracapsular (S72.0), pertrochanteric (S72.1), or subtrochanteric fracture (S72.2). The study population consisted of index cases of hip fracture (*i.e.* the first occurrence of hip fracture), among English residents aged 60 years or more, admitted to hospital. We excluded second hip fractures to avoid double-counting, since we were unable to distinguish reliably between two separate hip fracture events in HES.

Measurement of Deprivation

The index of multiple deprivation (IMD) was used as a proxy for each individual's level of socioeconomic deprivation [8]. IMD is a relative measure of deprivation for small areas of residence, termed lower super output areas (LSOAs) (a geographic area containing on average 1,500 residents). IMD is calculated using seven area level domains of deprivation: income, employment, education and training, health and disability, crime, barriers to housing and services, and the living environment. There are 32,482 LSOAs in England; each LSOA is assigned a score and a national rank for the individual domains of deprivation. A weighted sum of the ranks for each domain is used to calculate an overall IMD score based upon which LSOAs are ranked nationally. We used the IMD rank for a patient's LSOA and categorised patients into quintiles, with quintile 1 (Q1) being the least deprived group and quintile 5 (Q5) the most deprived group. HES IMD data fields are assigned based on a patients LSOA of residence, which is derived from the postcode recorded in the HES home address field at the time of hospital admission. HES used the IMD 2010 version for our financial years 2010/11 to 2014/15 [9]

Measurement of Costs

Using HES data, all finished consultant episodes (FCEs) recorded in the year before and after the index hip fracture were assigned a healthcare resource group code (HRG). FCEs represent a period of care in hospital under one consultant doctor, therefore a continuous spell in one or more hospitals may comprise several consecutive FCEs. A hip fracture spell, or length of stay (LOS), was defined as the index hip fracture admission, plus if applicable, planned hospital transfers for elective care and/or subsequent unplanned hospital transfers for emergency care (*i.e*. a superspell). LOS was calculated as the difference between the date of the index hip fracture admission and the final date of discharge from an NHS hospital.

HRG codes were assigned to each FCE using the "HRG4+ Reference Cost Grouper" software based on key information available in HES APC database [10]. HRG codes group clinically comparable treatments that use a broadly similar amount of NHS resources. Each FCE was assigned a cost (in £GBP) based on these HRG codes, taking account of excess bed days and unbundled HRGs, using the 2017/18 national reference costs [11]. Costs were aggregated to generate three key variables for analysis: 1) the cost of secondary care in the year following hip fracture (including the index admission); 2) the cost of the index admission only; 3) the secondary care costs in the year prior to hip fracture, for use as a covariate in regression analyses.

Covariates

Demographic, pre-fracture and post-fracture covariates were used in regression analyses exploring the relationship between deprivation and secondary care costs following hip fracture. Demographic covariates included age categories at the time of fracture (60-69, 70-79, 80-89, 90 years and above) and sex.

Pre-fracture covariates, potentially on the causal pathway between deprivation and post-fracture costs, were: pre-fracture mobility (from freely mobile (0) to no functional mobility (5)) [1]; secondary care costs in the year prior to fracture; dementia; other comorbidities (categorised as 0, 1 and 2 or more) included in the Royal College of Surgeons (RCS) Charlson score [12]; American Society of Anaesthesiologists (ASA) physical status classification (from healthy (1) to severe systemic disease that is a threat to life (4+)) [13]; use of bone protection medication pre-fracture; and fracture type. Comorbid conditions were identified using ICD-10 diagnosis codes recorded in the index hip fracture admission or any hospital admissions in the preceding five years. ASA grade is a simple 1 to 5 categorisation of a patient's physiological state that is used to predict perioperative risk [13]. Bone protection medications included, for example, bisphosphonates prescribed prior to the hip fracture admission.

Post-fracture covariates, which are potential mediators in any association between deprivation and secondary care costs following hip fracture, consist of delays to surgery beyond 36 hours, the annual volume of fracture admissions at the hospital site of admission (categorised into quarters based on the total number of admissions; small (0-280); below average (281-365)); above average (366-435) and large (435+)); mortality post-fracture (at 0-7; 7-30; 30-120; and 120-365 days) and care setting transitions. These transition variables were generated based on NHFD admission and discharge locations and identify, for example, patients requiring a new nursing or residential care home admission. We excluded post-fracture covariates from the regression that were proxy measures of hospital cost (*e.g*. length of stay and readmission) as our goal was to identify potentially modifiable pre- and post-fracture variables that mediate the association between deprivation and post-fracture hospital costs.

Statistical methods

We estimated the marginal cost of a hip fracture event estimating the incremental costs in the year following hip fracture, including the index stay, compared to the costs incurred in the year prior to hip fracture. We ran three regression models to explore the association between deprivation and secondary care costs post-fracture. Model 1 regressed post-fracture secondary care costs on deprivation quintiles controlling for age and sex. Model 2 explored the extent to which the association between deprivation and post-fracture costs was explained by pre-fracture factors by adding dementia, comorbidity, ASA grade, pre-fracture mobility, pre-fracture costs, pre-fracture bone protection medication and fracture type to Model 1. Model 3 explored whether the association between deprivation and post-fracture costs might be mediated by post-fracture factors by adding delays to surgery, volume of hip fracture admissions at site, mortality and care transitions to model 2.

Cost data are non-negative and often highly skewed reflecting a small number of very high cost patients. In the presence of skewed data, linear regression models may predict negative cost estimates for some individuals and produce biased estimates of coefficients [14]. Therefore, generalised linear models (GLM) were used. A Box-Cost test was used to identify which scalar powers resulted in the most symmetric transformed distribution with the aim of predicting the most appropriate link function [14]. A modified Park test was used to inform the choice of the most appropriate family function [14]. We used robust standard errors in all models to allow for potential misspecification of the family and link functions. Analysis of the modified Park test identified gamma and inverse Gaussian as the best fitting models. We present the gamma model as the primary analysis and provide the inverse Gaussian results in the supplementary material (Online Resource: Table 1). Akaike information criterion was used as a relative measure of the goodness of fit between the models [15].

In order to explore the extent to which individual pre and post- fracture covariates might mediate the relationship between deprivation and cost we employed a stepwise approach based on the methods of the 'chest' Stata post estimation command [16]. This method added all (model 3) covariates sequentially into the model starting with the covariate that produced the largest change in the coefficient on the deprivation index (IMD). Covariates were added successively in this way until all remaining variables were included in the model. The results were presented in a figure that identified the covariates that were most influential in mediating the association between deprivation and costs.

Final dataset

Linked HES-NHFD data were available for 228,112 hip fracture admissions in England between 01/04/2011 and 31/03/2015 (figure 1) [6]. Of these 9,205 (4.0%) patients were excluded due to being less than 60 years of age at the time of fracture, poor quality HES-NHFD data linkage, or missing data for deprivation or geographic region of residence. We have demonstrated elsewhere that descriptive characteristics are similar between groups [6]. A further 5,300 (2.3%) patients were dropped during the costing process as HRG codes could not be identified, these indivdiuals had similar demographics to those included (Online Resource: Table 2).The final linked HES-NHFD-ONS data set consisted of 213,607 patients.

Results

Patient population

The 213,607 patients had a mean age of 82.8 years (SD 8.4) and 72.7% were female. Prior to fracture 35.3% of patients were freely mobile without aids, whilst only 2.2% were fully immobile (table 1). Overall, 28% had dementia, 29.7% had at least one comorbidity (other than dementia) and 37.1% had two or more comorbid conditions (defined by RCS Charlson [12]). Displaced intracapsular fractures were the most common fracture type (48.4%). Prior to their hip fracture, only 9.7% of patients were taking any bone protection medication. At the time of fracture individuals from the most deprived locations (Q5) were younger (81.7 *vs*. 83.4 years), more likely to have dementia (28.9% *vs*. 26.8%), as well as other comorbidities (1 or more comorbidities 71.9% *vs* 62.6%), to have higher anaesthetic risk (ASA grade ≥3: 69.3% *vs*. 59.5%) and have greater impairment in pre-fracture mobility (lack of outdoor mobility 39.0% *vs*. 33.1%) compared to individuals from the least deprived areas (Q1). In the year before the hip fracture individuals from more deprived locations had higher mean inpatient costs (£2,671 (Q5) *vs.* £2,196 (Q1)).

Total hospital costs

The total mean cost of inpatient care in the year following hip fracture was £12,949 per patient (95% CI £12,931 to £12,984). Of this £9,445 (95% CI £9,424 to £9,465) was incurred during the index admission and £3,504 (95% CI £3,471 to £3,530) through readmissions costs. The mean per person inpatient cost in the year prior to the hip fracture in this population was £2,388 (95% CI £2,359 to £2,416). Therefore, the incremental cost after the hip fracture was estimated to be £10,561 per patient. Given there are approximately 60,060 hip fracture admissions in England each year [1], the total additional yearly secondary care cost potentially attributable to hip fractures was calculated to be approximately £634.3 million.

Role of deprivation

Following hip fracture, those in the most deprived areas (Q5); had a longer LOS during the initial hospitalisation (24.0 *vs*. 22.7 days), were more likely to have surgery delayed beyond 36 hours (12.0 *vs* 9.1%), had a higher mean number of readmission days (2.7 *vs*. 2.5) and had higher mortality at 365 days (29.7% *vs*. 26.3%) compared to those in Q1 (table 2). Mean inpatient costs increased linearly through the IMD quintiles (Q1-Q5) from a mean value of £12,505 for Q1 to £13,552 in Q5 (Figure 2).

The results from the three regression models are shown in table 3. When controlling for age and sex (model 1), patients living in the most deprived areas (Q5) incurred on average £1,120 (95% CI £993 to £1,247) higher inpatient costs than those from the least deprived locations (Q1). If it were possible for the health and social inequalities associated with deprivation to be removed and consequently all patients were to experience the same costs as those in Q1, then the NHS would save approximately £28.8 million per year in hip fracture associated hospital costs.

The association between deprivation (Q5 compared to Q1) and costs reduces by 48.8% to £574 (95% CI £446 to £692) when the pre-fracture covariates are added in model 2. This association is only modestly further reduced by 4.5% to £523 (95% CI £412 to £634) when the post-fracture covariates are added in model 3. This suggests that the association between deprivation and costs is not substantially mediated through surgical delays, early mortality or transitions of care.

Non-dementia comorbidities had the largest mediatory effect on the association between deprivation and hospital costs (Figure 3). The addition of this variable alone to model 1 attenuated the association between deprivation and post-fracture costs by 32.5%. The second most influential variable was ASA grade which reduced the association by a further 14.5%. The other covariates had a relatively small impact on the estimated association between deprivation and costs.

Predictors of inpatient costs following hip fracture

Adjusting for all covariates in model 3, women had lower inpatient costs by £990 (95% CI £911 to £1,071) than men. There was a non-linear association between age and costs, with the 80-89 year age category incurring the highest costs (£580; 95% CI £439 to £722) when compared to the 60 -69 year age group. Subtrochanteric fractures were associated with the highest costs compared to un-displaced intracapsular fractures (£857; 95%CI £673 to £1,041). Having dementia was associated with slightly lower inpatient costs in model 3 (£-210; 95%CI £-295 to £-124). Other comorbid conditions however, increased costs substantially by up to £2,671 (95% CI £2,582 to £2,759), for those with two or more comorbidities compared to having none. Similarly, better physical status, measured by ASA grade, was associated with lower post-fracture hospital costs. Pre-fracture mobility had a non-linear association with inpatient costs. Those who were ‘mobile outdoors with two aids or a frame’, incurred the highest cost, £1,843 (95% CI £1,691 to £1,996) more than those who were freely mobile.

We found no evidence of economies of scale at hospital sites with a larger volume of hip fracture admissions. Patients discharged back to a nursing (£-2,829; 95% CI £-2,964 to £-2,693) or a residential home (£2,093; 95% CI £-2,213 to £-1,973) had lower costs than patients discharged to their own home. Conversely, being discharged to a nursing home for the first time added on average £1,102 (95% CI £920 to £1,285) and being discharged to a residential home for the first time added £1,044 (95% CI £843 to £1,245) to inpatients costs.

Mortality had a non-linear but very substantial impact on inpatient costs in the year following a hip fracture. Death occurring within 7 days of the hip fracture reduced hospital costs by £6,135 (95% CI £-6,247 to £-6,023) compared to patients who survived to 365 days. However, deaths occurring in the period 120-365 days post-fracture increased costs by £4,049 (95% CI £3,911 to £4,187).

Discussion

Key Findings

We estimate that in England the total annual inpatient costs attributable to hip fractures in patients aged 60 years and over is approximately £634.3 million. There is a consistent relationship between higher levels of deprivation and higher inpatient costs following a hip fracture. If the health and social inequalities associated with deprivation and the resulting costs could be reduced to equate to the levels of those in the least deprived quintile, then NHS England could theorectially save £28.8 million per year in hip fracture associated hospital costs alone. Much of the association between deprivation and costs was explained by pre-existing health differences between patients living in the most and least deprived areas. Most notably the inclusion of comorbidities and anaesthetic (ASA) risk grade in the regression model reduced the observed association between deprivation and post-fracture costs by 32.5%. and 14.5% respectively. While care transitions to a new nursing or residential home were associated with higher post-fracture costs, there was little evidence that these transitions were any more costly for patients living in deprived areas.

Strengths and Limitations

This is the first study to explore in detail the role of deprivation in explaining hospital costs incurred following a hip fracture. Whilst other cost analyses have included proxy measures of deprivation as covariates in hip fracture models [2, 17], until now deprivation has not been the focus of such work. Our analysis took advantage of a very large nationwide sample of patients admitted over a four-year period. This allowed us to precisely estimate predictors of post-fracture costs, which should be generalisable across all areas of England. Data linkage between the HES APC database, the NHFD and ONS mortality database enabled us to utilise both pre-fracture NHFD variables, whilst also capturing care transfers and readmissions at any NHS hospital in England.

IMD is a proxy measure of deprivation based on area-level deprivation within LSOAs, rather than the individual's actual circumstances. Therefore, the average level of deprivation within a small area might not be representative of all individuals residing in that area [18]. Therefore, the association observed between area-level deprivation and costs is vulnerable to 'ecological fallacy' and may not reflect the true association. We are unable to test this formally as individual-level measures of deprivation are not available within the routinely collected datasets we analysed. Furthermore, while hospital costs comprise an important element of the care that patients receive post-fracture, other care sectors, particularly primary care, residential care, informal care and social services are also essential for rehabilitation and long-term care. Perhaps reassuringly for our analyses, Lambrelli et al. [3] found that only 3.9% of their total annual post-hip fracture cost estimate derived from outpatient, primary care and/or pharmacy costs, with the remaining 96.1% attributable to inpatient costs. The addition of all community care costs post fracture would produce a higher total cost than we have estimated.

The quality of routinely collected national clinical audit data may be lower than data collected for primary research. However, the HES dataset is subject to regular data quality checks and importantly it is used to reimburse hospital activity [19], therefore data completeness on key variables is high. A major limitation of observational studies is the inability to demonstrate causation. Thus, rather than demonstrating a causal relationship between deprivation and hospital costs, we have identified a strong association, and demonstrated that this is substantially attenuated when pre-fracture covariates, specifically comorbidities and physical status, are considered in the model.

Although efforts were made to include a wide range of covariates, a substantial proportion (~47%) of the relationship between cost and deprivation remains unexplained. This, may in part, arise from measurement error; the RCS Charlson co-morbidity index was specifically developed and validated for use in hospital administrative data [12]. However, because it relies on comorbidities recorded during hospital admissions it may miss comorbidities managed predominantly in primary care. A richer measure of comorbidity, including primary care data, might explain more of the relationship between deprivation and post-fracture costs. There are likely to be unobserved variables, such as health-related behaviours (*e.g.* nutrition, smoking, alcohol consumption, physical activity), and other environmental factors (*e.g.* social isolation, housing conditions) that might also mediate the relationship between deprivation and post-fracture costs. The ASA grade should act as a proxy measure for some of these health-related behaviours, such as smoking, heavy alcohol consumption, undernutrition and obesity, which may explain its additional contribution to model 2, over and above ICD-10 coded diseases (other comorbidities).

Linkage to social care databases was not possible, hence detail regarding funding for care transitions and social support at home was not available. It is possible that those who are least deprived, potentially with private funds available, may be able to access private care more promptly with consequent shorter lengths of stay in hospital and lower hospital costs.

Comparison with previous work

We estimated the total inpatient cost of a hip fracture admission to be £12,949 (95% CI £12,931 to £12,984) per year over the period 2011-2015. This cost is similar to those from Leal et al. [2] and Lambrelli et al. [3] who estimated costs for the year following hip fracture of £14,163 (over the period 1999-2013) and £15,689 (2006-2011) respectively. Their figures included outpatient and emergency department costs [2] and Lambrelli et al. was also able to include primary care costs [3]. Our costs exceed those from an older study of the hip fracture care pathway which included inpatient and outpatient activity, which estimated a mean cost of £8,242 in 2009/10 [17]. Our estimate of the total yearly NHS England cost attributable to hip fracture was £634.3 million compared to an estimate of £869 million across the UK in Leal et al.2016 [2]. Part of the inconsistency is explained by use of different annual hip fracture incidence estimates. Our conservative estimate for England only, based on the 2017 NHFD annual report, counted approximately 20,000 fewer hip fractures than Leal et al.

Whilst international studies have estimated the cost of care following a hip fracture, none has addressed the role of deprivation. The incremental direct health care costs of hip fracture in Manitoba province, Canada, was estimated to be CAN$25,306 (~£15,000) higher in women and CAN$21,396 (~£13,000) higher in men in 1997-2002, compared to a control group one year [20]. Cost estimates from the US have been higher, where comorbidities have also been identified as principal driver for readmissions and 1st-year costs [21, 22]. More widely, our findings support a significant association between deprivation and hospital costs in the UK [4, 5], as have been seen in other high-income economics, *e.g.* Germany and the Netherlands [23, 24].

Policy implication and future research

We have previously shown, in an examination of secular trends, that absolute inequalities in hip fracture incidence have persisted, and in women widened, over more than a decade in England [25]. Here we demonstrate further health inequality in terms of outcomes post hip fracture, which appear to largely be explained by pre-fracture health status. It is likely that similar adverse but modifiable lifestyle factors, associated with deprivation, in part underlie both these observations. Higher rates of smoking, alcohol consumption, obesity and lower levels of physical activity are commonly associated with deprivation, and the consequences of these likely explain the higher annual pre-fracture costs we found to be associated with deprivation. Whilst nationally, smoking prevalence has declined over recent years [26], rising alcohol-related deaths are strongly linked to deprivation [27], as are rates of obesity [28].

Half of older adults who sustain a hip fracture, report a prior fragility fracture [29, 30]. Hence, Fracture Liaison Services (FLS) aim to systematically identify all patients who sustain a fragility fracture in order to investigate and intervene to reduce future falls and fracture risk [31, 32]. Such interventions include advice regarding smoking cessation, alcohol reduction, regular weight-bearing exercise and the prescription of anti-resorptive medications. Concerningly, in our study we found only 9.7% patients were taking anti-resorptive medication at the time of hip fracture, potentially reflecting the inadequacy of such FLSs during the study period (2011-15). In recent years, initiatives such at the Royal College of Physicians of London, National FLS Database audit has aimed to improve FLS provision; however, their most recent report has shown wide variation in the provision, with poorer coverage particularly in the North of England, where deprivation, and its impact on fracture risk, are greatest [33, 34]. Taken together, it seems those populations in greatest need may be least provided for. At the first UK House of Lord's Science and Technology Select Committee inquiry into enabling healthier living in older age (2019-ongoing), the new Chief Medical Officer (CMO) for England, identified lifestyle factors including smoking, alcohol consumption and obesity to be key determinants of growing health inequalities amongst older people in the UK. Current proposals by the CMO, include introduction of the Composite Health Index, to provide transparent and accountable measurement of relative health inequalities [35].

Among people living with osteoporosis, 42% report feeling socially isolated [36]. Poorer social support is strongly linked to greater levels of deprivation [28]. Social isolation is thought to impact survival, to a similar level as smoking, and to a greater extent than obesity [37].Increasing recognition of loneliness is influencing policy [38], whether downstream initiatives in turn impact health costs is currently unknown.

Whilst in our analyses, deprivation predicted surgical delay, with 2.9% more of those in the most deprived areas, compared with the least, waiting over 36 hours for surgery, this may be explained by the need to stabilise active comorbidities prior to anaesthesia, rather than differences in the provision of care. However, in the UK, socioeconomically deprived patients have been shown to be much less likely to receive total hip replacement (THR) for an intra-capsular hip fracture, despite clear NICE guidance [39], meaning that optimal treatment for older adults with hip fractures does depend upon where and when patients present to hospital [40]. Further research is warranted to understand the causes of such in-hospital treatment decisions.

Post-hip fracture rehabilitation represents a further area where there is a potential to reduce health inequalities [41-43]. We have previously shown wide variation in availability of community rehabilitation services, determined largely by postcode according to local commissioned services [44]. Dementia is common in the context of hip fracture, yet those with cognitive impairments are systematically excluded from trials of post-hip fracture interventions[45], despite this group potentially have the most to gain[43]. Appropriate and equitable commissioning of post-fracture rehabilitation services is required, to ensure fair access governed by clinical need and patient choice rather than geography.

In our study, compared with pre-fracture factors, post-fracture variables had less of an impact on the relationship between deprivation and costs. Consequently, the ability for policy makers to intervene in the post hip fracture period to reduce the impact of inequalities is limited. The case for upstream life course intervention to promote healthy ageing, prevent fractures and falls, manage comorbid conditions and adverse health-related behaviours, and potentially address the built environment and levels of social support, in the most deprived population is clear but challenging to implement[46].

Despite linkage across detailed national-level databases, approximately half of the association between deprivation and post-fracture costs remained unexplained in our model, thus further research examining drivers of this relationship is needed.

Conclusion

From detailed analysis of 213,607 patients aged 60+ years, sustaining a hip fracture in England between 2011 and 2015, we have shown the total annual inpatient costs attributable to hip fractures to be approximately £630 million, based on an incremental mean cost of inpatient care in the year following hip fracture of £10,561. The total cost of inpatient care following a hip fracture is £12,949 per patient of which £9,445 is incurred during the index admission and £3,504 through readmissions costs. We have identified a consistent relationship between higher levels of deprivation and higher inpatient costs following a hip fracture. After taking account of differences in age and sex, patients living in the most deprived areas (Q5) incurred on average £1,120 higher inpatient costs than those in the least deprived locations (Q1). If costs could be reduced to the levels of those in the least deprived quintile, then NHS England could save £28.8 million per year in hospital costs alone. Much of the association between deprivation and costs was explained by poorer pre-existing health amongst patients living in the most deprived areas. These findings have implications for public health provision and social policies applicable to those who are most deprived, which should aim to address adverse socioeconomic circumstances, lifestyle factors, promotion of physical activity, and efforts to reduce social isolation. Further research is warranted to investigate in-hospital decision making as it applies to individuals with varying deprivation backgrounds.

Figures and Tables

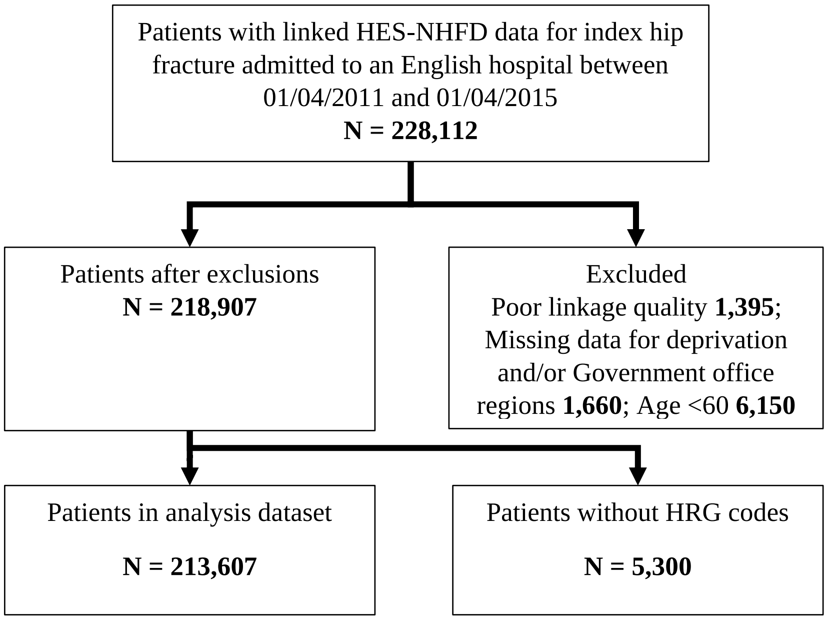

Fig.1 *Eligibility Flowchart*

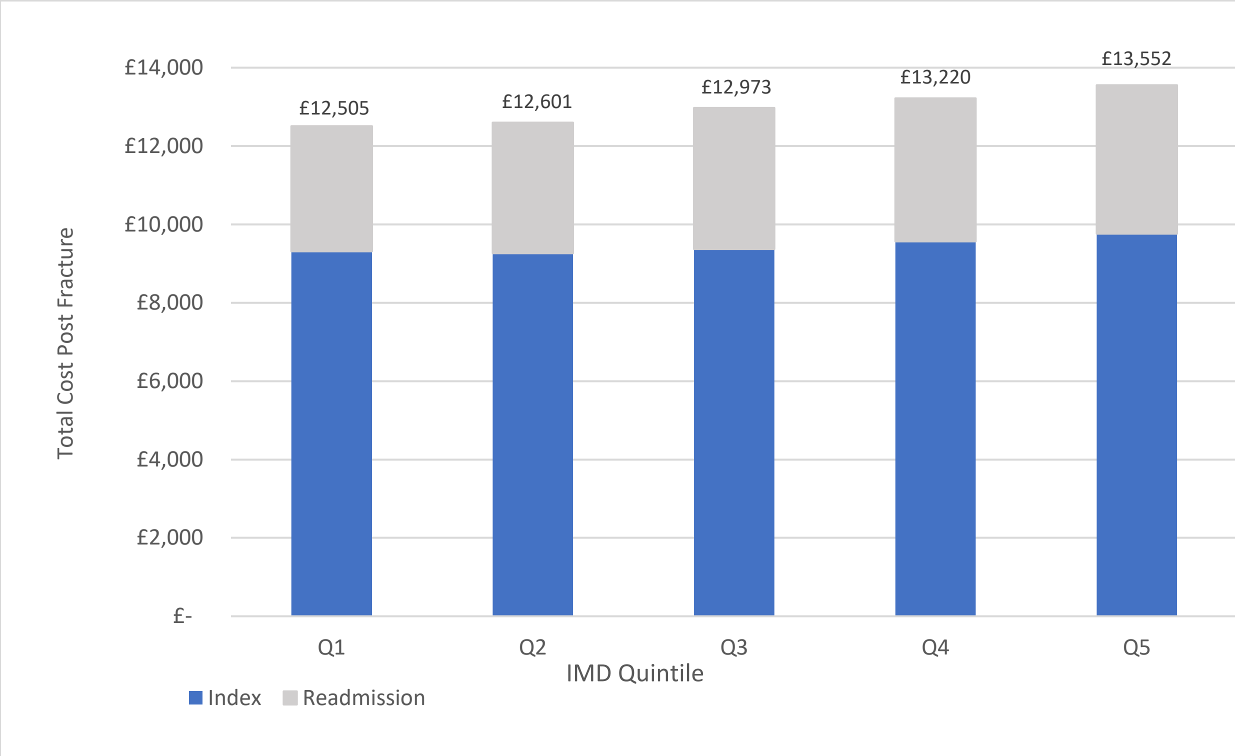

Fig.2 *Inpatient costs in NHS hospitals in England in the year after hip fracture (2011-2015): All patients stratified by quintiles of the index of multiple deprivation (IMD)*

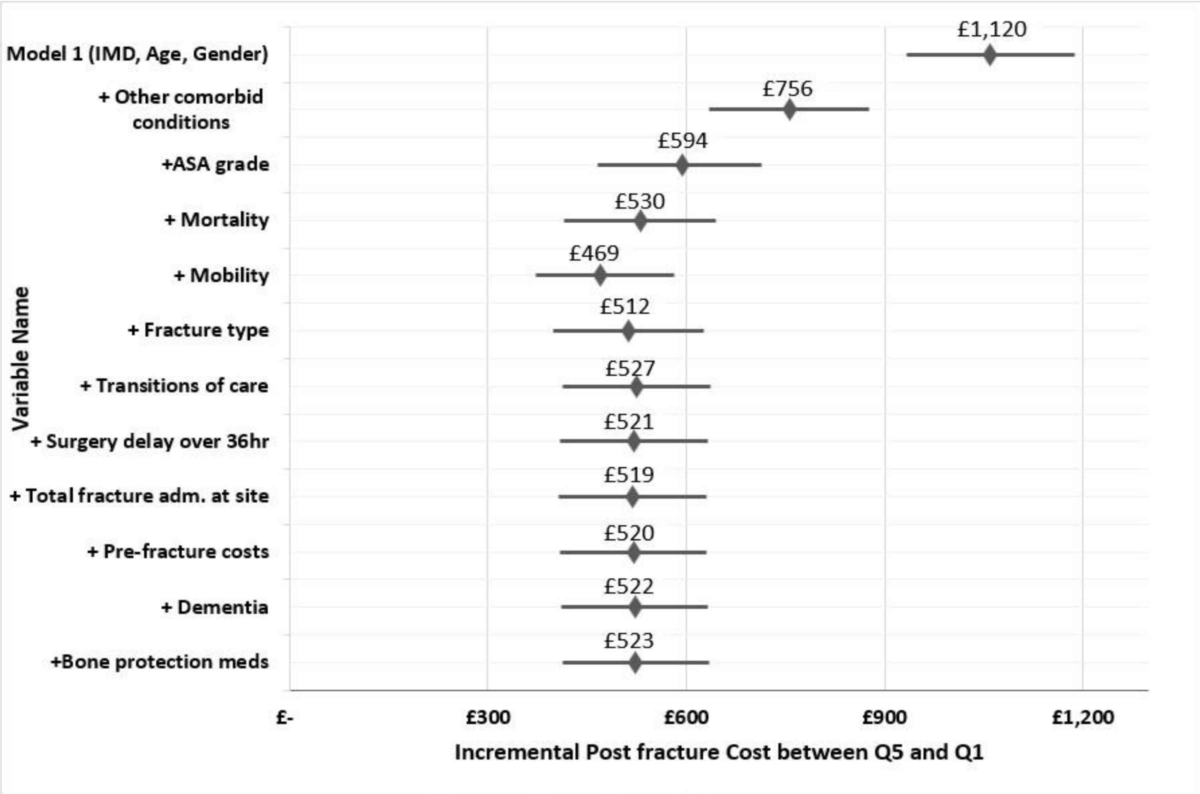

Fig.3 *Mediated coefficient of deprivation on post hip fracture costs following stepwise addition of all covariates*

__Table 1__ Characteristics of patients aged 60+ admitted to NHS hospitals in England prior to fracture (2011-2015)

Deprivation quintile	[a]Q1 (n=42,641)	Q2 (n=46,003)	Q3 (n=45,900)	Q4 (n=41,369)	Q5 (n=37,684)	All (n=213,607)	P-value[b]
Mean age (SD)	83.4 (8.2)	83.1 (8.3)	83.0 (8.3)	82.7 (8.5)	81.7 (8.7)	82.8 (8.4)	<0.001
Female %	72.2	73.2	73.0	72.8	71.3	72.7	<0.001
Dementia %	26.8	27.9	28.3	29.2	28.9	28.2	<0.001
Other comorb. %							
1	29.1	29.7	30.1	29.6	29.8	29.7	<0.001
2+	33.5	34.8	36.5	39.3	42.1	37.1	<0.001
ASA Grade[c] %							
I	2.8	2.5	2.2	1.8	1.4	2.1	<0.001
II	31.5	29.3	27.9	25.2	22.5	27.5	<0.001
III	49.3	51.0	52.2	54.1	54.6	52.2	<0.001
IV and V	10.2	11.1	11.6	12.8	14.7	12.0	<0.001
Missing	6.2	6.1	6.1	6.2	6.8	6.3	0.002
Pre-fracture mobility %							
Freely mobile	35.6	34.1	32.4	30.7	29.6	32.6	<0.001
Mobile with one aid	17.8	17.7	17.3	16.6	15.7	17.1	<0.001
Mobile with two aids/frame	7.8	7.8	8.2	8.1	7.3	7.8	0.397
Some indoor mobility	31.3	31.3	32.6	34.5	36.7	32.9	<0.001
No functional mobility	1.8	1.9	2.1	2.2	2.3	2.1	<0.001
Missing	6.8	7.2	7.5	7.8	8.4	7.5	<0.001
Pre-fracture bone protection %	9.6	9.7	9.6	9.8	9.7	9.7	0.368
Mean Pre-fracture annual costs	£2,196	£2,220	£2,411	£2,490	£2,671	£2,388	<0.001
Admitted from %							
Own home	78	76	76	75	76	76	<0.001
Prior NHS care	4	4	4	4	5	4	<0.001
Residential or Nusing home	17	19	19	20	18	19	<0.001
Other/missing	1	1	1	1	1	1	0.001
Fracture type %							
Intracapsular undisplaced	10.1	10.2	10.4	10.1	10.8	10.3	0.006
Intracapsular displaced	50.5	49.4	48.5	47.5	46.1	48.4	<0.001
Intertrochanteric	32.9	34.0	34.3	35.5	36.3	34.5	<0.001
Subtrochanteric	5.8	5.6	5.9	5.9	5.8	5.8	0.176
Other	0.9	0.9	1.0	1.0	0.9	0.9	0.129

[a] IMD quntiles Q1- Least Deprived and Q5 Most deprived areas
[b] From univariable ordered logit regression
[c] American Society of Anaesthesiologists Grade

Table 2 *Post hip fracture outcomes of patients aged 60+ admitted to NHS hospitals in England prior (2011-2015)*

Deprivation quintile	[a]Q1 (n=42,641)	Q2 (n=46,003)	Q3 (n=45,900)	Q4 (n=41,369)	Q5 (n=37,684)	All (n=213,607)	P-Value[b]
Length of stay days (SD)	22.7 (21.6)	22.6 (21.1)	23.0 (21.1)	23.8 (21.8)	24.0 (21.6)	23.2 (21.4)	<0.001
Total readmission days (SD)	2.5 (10.0)	2.6 (10.1)	2.7 (10.1)	2.7 (10.2)	2.7 (10.4)	2.6 (10.1)	0.001
Surgery delayed over 36hr %	9.1	9.7	10.3	11.2	12.0	10.3	<0.001
Volume of fracture admissions at site %							
Small	21.1	23.6	27.5	27.6	25.6	25.1	<0.001
Below average	23.8	23.6	22.6	25.5	29.6	24.8	<0.001
Above average	30.8	26.9	24.1	21.6	22.3	25.2	<0.001
Large	24.3	25.9	25.8	25.3	22.5	24.8	0.122
Transitions of care %							
Moved into nursing home	5.1	4.6	4.5	4.5	4.3	4.6	<0.001
Moved into residential home	3.5	3.9	3.9	4	3.9	3.9	0.006
Ongoing NHS care	10.3	10	10.6	9.9	8.9	10	<0.001
Remained in residential care	10	5.5	6.6	6.6	7	6.4	<0.001
Remained in nursing care	4.6	4.2	4.4	4.3	4.2	4.3	0.027
Remained at home	46.8	45.4	43.9	42.6	43.7	44.5	<0.001
Died before discharge	7.5	8.0	8.2	8.4	9.2	8.2	<0.001
Other transitions	16.7	17.4	18.1	19.3	19.6	18.2	<0.001
Mortality %							
Alive at 365 days	73.7	72.7	71.5	70.6	70.2	71.8	<0.001

[a] IMD quntiles Q1- Least Deprived and Q5 Most deprived areas
[b] From univariable ordered logit regression.

Table 3 *GLM regression results*

	Model 1[a] (95% CI)	Model 2 [b] (95% CI)	Model 3[c] (95%CI)
IMD (Ref Q1 (least deprived))			
Q5 (most deprived)	£1,120** (£993 to £1,247)	£574** (£446 to £692)	£523** (£412 to £634)
Q4	£768** (£647 to £888)	£ 394** (£281 to £507)	£324** (£219 to £431)
Q3	£503** (£387 to £618)	£ 287** (£179 to £395)	£229** (£127 to £330)
Q2	£116* (£3 to £230)	£ 23 (£-84 to £130)	£ -2 (£-103 to £100)
Female	£-1,742** (£-1,830 to £-1,654)	£ -1,070** (£-1,155 to £-985)	£-990** (£-1,070 to £-911)
Age (Ref 60-69)			
70 to 79	£1,109** (£929 to £1,290)	£ 555** (£395 to £717)	£416** (£264 to £569)
80 to 89	£1,537** (£1,370 to £1,696)	£ 786** (£637 to £ 934)	£ 580** (£439 to £722)
90 plus	£1,220** (£1,047 to £1,393)	£ 359** (£198 to £ 520)	£275** (£121 to £428)
Dementia		£-745** (£-827 to £-662)	£-210** (£-295 to £-124)
Other Comorbidity			
1		£ 1,058** (£974 to £1,142)	£1,019** (£940 to £1,099)
2+		£ 2,706** (£2,612 to £2,798)	£2,671** (£2,582 to £2,759)
ASA[a] Grade (Ref ASA III)			
ASA I		£-2,764** (£-2,951 to £-2,578)	£-2,635** (£-2,818 to £ -2,451)
ASA II		£-1,343** (£-1,427 to £-1,259)	£-1,328** (£-1,408 to £-1,247)
ASA IV and V		£217** (£104 to £330)	£531** (£426 to £637)
ASA missing		£-1,855** (£-2012 to £-1,698)	£-1,727** (£-1,873 to £-1,581)
Pre-fracture mobility (Ref freely mobile)			
Outdoors with one aid		£ 1,444** (£1,328 to £1,559)	£1,240** (£1,131 to £1,349)
Outdoors with two aids or frame		£ 2,009 ** (£1,847 to £2,172)	£1,843** (£1,691 to £1,996)
Indoor mobility only		£1,195** (£1,095 to £1,296)	£ 1,338** (£1,241 to £1,435)
No functional mobility		£-512** (£-763 to £-261)	£164 (£-77 to £405)
Mobility missing		£1,335** (£1,170 to £1,500)	£1,446** (£1,292 to £1,601)
Pre-fracture costs (1 SD change in costs)		£708** (£667 to £749)	£655** (£617 to £693)

Pre-fracture bone protection medication		£324** (£203 to £445)	£226** (£113 to £339)
Fracture Type *(Ref:* Intracapsular-un-displaced*)*			
Intracapsular displaced		£731** (£611 to £851)	£686** (£572 to £800)
Intertrochanteric		£332** (£205 to £459)	£199** (£79 to £319)
Subtrochanteric		£985** (£790 to £1,180)	£857** (£673 to £1,041)
Other		£306 (£-115 to £726)	£334 (£-64 to £732)
Fracture type missing		£-643 (£-1,450 to £163)	£-953 (£-1,704 to £-201)
Surgery delayed over 36 hours			£191** (£73 to £309)
Fracture admission volume at site (*Ref small*)			
Below average			£-8 (£-99 to £83)
Above average			£-101* (£-192 to £-10)
Large			£422** (£328 to £517)
***Transitions of Care* (*Ref: Home to Home*)**			
Residential care to residential care			£-2,093** (£-2,213 to £-1,973)
Nursing home to nursing home			£-2,829** (£-2,964 to £-2,693)
Non-hospital to ongoing NHS care			£2,780** (£2,628 to £2,932)
Non-nursing home to nursing home			£1,102** (£920 to £1,285)
Non-residential care to residential care			£1,044** (£843 to £1,245)
Died before discharge			£962** (£798 to £1,125)
Other pairings			£ 434** (£333 to £535)
Mortality (Ref: survived 365 days)			
Died before7 days			£-6,135** (£-6,247 to £-6,023)
Died 7 to 30 days			£-3,432** (£-3,545 to £-3,319)
Died 30 to 120days			£356** (£253 to £459)
Died 120 to 365days			£4,049** (£3,911 to £4,187)
Constant	£ 12,460** (£12,293 to £12,629)	£10,416** (£10,252 to £10,582)	£10,085** (£9,926 to £10,245)
AIC[e]	20.93	20.91	20.88

*p-value <0.05 ** p-value < 0.01

[a] Total impact of deprivation (controlling for age and sex)

[b] Pre-fracture covariates

[c] Post-fracture covariates

[d] American Society of Anaesthesiologists Grade

[e] Akaike's Information Criterion

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